CHEMICAL COMPOSITION OF AVOCADO FRUITS [1]

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INTRODUCTION

In a previous paper by the writer (*6*) [2] it was pointed out that the distribution of the stomata in fruits of avocado (*Persea gratissima* Gaertn.) is governed by growth and is related to the water loss and aeration of the fruit. As a result of this work, the number of stomata, the water loss, and the permeability of avocado fruits were shown to be greater in the tip than in the stem halves. The nonuniformity of these factors in the various portions of the fruit skin suggested the need for a study of the chemical composition of the various portions of avocado fruits.

Data regarding the composition of avocado fruits are limited primarily to the values for the fat and sugar content, for it is these constituents that determine in a large measure the quality of the fruits. Little is known regarding the iron, copper, and manganese content, although these elements are of considerable importance in plant and animal nutrition.

Avocado trees frequently are grown in districts in which the soil or irrigation water or both contain large concentrations of salts, chiefly chlorides or sulphates. In such locations the leaves may be seriously tip-burned. So far as the author is aware, no data exist from which it is possible to learn the extent of the accumulation of chloride, sulphate, and other constituents in the fruits. This paper presents data regarding not only the occurrence and distribution of certain constituents in avocado fruits but also some of the changes that accompany increasing maturity.

PREVIOUS WORK

The composition of a single sample of ash in avocado fruit is reported by Jaffa and Goss (*9*). Church and Chace (*1*) found that a marked increase in the fat content during the rapid development of the fruits was accompanied by a decrease in total sugar.

Attention is called by Church and Chace (*1*) to an analysis in which they found the outer half of the fresh pulp next to the skin to contain 1.54 percent of ash as compared with 1.36 percent in the inner half next to the seed. Differences of this kind in other fruits have recently been referred to by Haas and Klotz (*8*), Drain (*3*), and Tucker (*12*), and in the vegetative portions of plants by Mason and Maskell (*10*), Frear (*4*), Tukey and Green (*13*), and Cowell (*2*). Such investigations have shown the nonhomogeneous constitution of the tissues that make up certain organs, whether these be vegetative or reproductive in nature.

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[2] Reference is made by number (italic) to Literature Cited, p. 686.

METHODS OF ANALYSIS

Unless otherwise stated, the fruits[3] after being picked from the trees, were wiped free of dust, washed with distilled water and dried with filter paper, and then weighed. In some cases the pulp of the fruits was cut into halves from stem end to tip end, in other cases these halves were further subdivided into inner and outer portions. The seed and skin were removed and weighed, care being taken to free the skin from adhering pulp.

Finely cut samples of fresh material (100 g) were used for the determination of inorganic constituents and were dried below 65° C. in a current of air in a large oven. Samples of fresh material (25 to 50 g) for the determination of total and reducing sugars consisted of thin segments which were finely cut and weighed prior to being dropped into enough 95-percent boiling alcohol to secure a strength of 80 percent. The boiling of the alcohol was continued for a short time in order to kill the tissue. The Erlenmeyer flasks (300 cc) were then tightly closed with stoppers protected with tinfoil. When cool, the alcohol was measured and run into a 500-cc volumetric flask used for sugar extraction. The avocado material was finely macerated in a mortar with coarsely pulverized quartz and was transferred to the 500-cc flask with the aid of 80-percent alcohol. The alcohol was then reduced to 50 percent strength and the total and reducing sugars were determined by the method used by Haas and Klotz (*8*).

The fat determinations were made on samples of fresh material (0.5 to 1.0 g) by the use of anhydrous ether extractions from thimbles containing anhydrous copper sulphate, sand, and asbestos layers. The other chemical analyses for the most part were conducted by the methods employed with date fruits by Haas and Bliss (*7*). In many cases sulphuric acid was added to the dry matter before ashing (muffle furnace at low heat combined with leaching of the ash) in the determination of potassium. No appreciable losses of potassium were found when the acid treatment was omitted.

ANALYSES

DRY MATTER IN PULP

The results for freshly picked fruits (table 1) show somewhat more dry matter in the tip than in the stem portions of the pulp (without skin). Earlier determinations were not so uniform, largely because the fruits were not obtained directly from the trees.

The tip halves of avocado leaves (table 2) from which the midribs have been removed, contain greater percentages of dry matter in the fresh weight than do the stem halves. In this regard the leaves and fruits resemble one another, and it is of interest to note that fruits originate from megasporophylls, which are modified leaves.

ACIDITY OF PULP

No reference to the reaction of avocado pulp has been found in the literature.

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[3] All fruit samples, unless otherwise specified, were collected at the Citrus Experiment Station.

TABLE 1.—*Dry matter in pulp (without skin) from different portions of avocado fruits of several varieties collected on different dates, 1930*

Variety and date of collection	Fruits	Dry matter on fresh-weight basis in—								
		Stem halves	Tip halves	Stem-end thirds	Middle thirds	Tip-end thirds	Stem-end quarters	Second quarter from stem ends	Third quarter from stem ends	Tip-end quarters
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Blake:										
Aug. 21	16	20.74	21.34	--------	--------	--------	--------	--------	--------	--------
Aug. 25	15	22.70	22.64	--------	--------	--------	--------	--------	--------	--------
Aug. 28	5	22.35	22.99	--------	--------	--------	--------	--------	--------	--------
Benik:										
Aug. 21	4	11.73	12.37	--------	--------	--------	--------	--------	--------	--------
Aug. 25	10	12.90	13.78	--------	--------	--------	--------	--------	--------	--------
Puebla:										
Aug. 21	17	12.03	12.81	--------	--------	--------	--------	--------	--------	--------
Aug. 25	15	14.10	14.67	--------	--------	--------	--------	--------	--------	--------
Aug. 28	5	12.48	13.77	--------	--------	--------	--------	--------	--------	--------
Fuerte:										
Aug. 21	10	13.24	14.12	--------	--------	--------	--------	--------	--------	--------
Aug. 25	4	13.82	14.37	--------	--------	--------	--------	--------	--------	--------
Do	10	14.98	15.57	--------	--------	--------	--------	--------	--------	--------
Blake:										
Aug. 21	8	--------	--------	20.61	20.50	21.43	--------	--------	--------	--------
Do	8	--------	--------	21.10	21.16	22.19	--------	--------	--------	--------
Puebla seedling:										
Sept. 3	5	--------	--------	19.06	19.54	21.32	--------	--------	--------	--------
Sept. 5	8	--------	--------	19.67	21.09	22.30	--------	--------	--------	--------
Sharpless(?) seedling:[1]										
Nov. 22	1	--------	--------	--------	--------	--------	25.49	27.12	27.27	28.47
Do	1	--------	--------	--------	--------	--------	25.84	25.52	26.34	28.16

[1] Fruits 7 cm largest diameter by 19 cm long.

TABLE 2.—*Dry matter in tip and stem halves from four varieties of mature avocado leaves, with midribs removed*

Variety	Leaves	Dry matter on fresh-weight basis	
		Tip halves	Stem halves
	Number	*Percent*	*Percent*
Blake	180	37.19	35.35
Fuerte	194	38.94	37.89
Benik	189	33.72	32.42
Puebla	194	35.48	34.38

In June 1934 several mature avocado fruits were picked from a Guatemalan seedling tree and allowed to soften. One of the fruits, when edible, was cut into stem and tip halves. The seed was discarded and the skin removed. The pulp of the stem and tip halves was divided into inner and outer portions. The four samples of pulp were placed in beakers, and a minimum of distilled water was added to permit the maceration of the pulp into a paste. The pH values (table 3) were then determined by means of the quinhydrone electrode.

The actual acidity increases outwardly toward the skin and also increases from the stem toward the tip, in the inner as well as in the outer portions.

The pulp from another fruit of the same lot which was just beginning to soften but was not edible as yet, was cut into very small pieces and then macerated in a mortar with the aid of coarsely pulverized quartz. The pH values recorded in table 3 confirm the results obtained in the first experiment.

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TABLE 3.—*pH values in different portions of mature avocado pulp (without skin) before and after it became edible, fruit from Guatemalan seedling being used*

Portion of fruit used	Soft and edible pulp	Hard, inedible pulp
	pH	*pH*
Stem half, inner portion	6.86	6.56
Stem half, outer portion	6.72	6.46
Tip half, inner portion	6.64	6.52
Tip half, outer portion	6.44	6.34

The pulp of avocado fruits is more acid near the skin. This indicates that the outer tissues are better aerated and that the carbon dioxide which tends to make the tissue more alkaline (*11*) is more quickly removed. The greater number of stomata in the tip half (*6*) probably also permits greater oxidation than in the stem half.

FAT CONTENT

Samples of avocado fruits were tested for fat content immediately after they were picked. Long, thin slices of pulp (without skin or seed) were cut in a direction extending from the stem or tip ends to the central crosscut, and these slices, in turn, were cut into narrow pieces. After the samples were weighed, the fat was extracted as described under Methods of Analysis.

The percentage of fat found in the fresh pulp of avocado fruits of different varieties picked at various stages of development are given in table 4. The fat content increased with increasing maturity of the fruits, as was found by Church and Chace (*1*). The fat content of the stem and tip halves showed no uniform differences.

TABLE 4.—*Fat content of the pulp (without skin) from the stem and tip halves of avocado fruits of several varieties in relation to time of collection*

Variety and date of collection	Fruits	Fat on fresh-weight basis		Variety and date of collection	Fruits	Fat on fresh-weight basis	
		Stem half	Tip half			Stem half	Tip half
Fuerte:	*Number*	*Percent*	*Percent*	Benik—Continued.	*Number*	*Percent*	*Percent*
Sept. 23, 1930	7	5.40	5.67	Feb. 16, 1931	8	11.35	11.47
Oct. 23, 1930	2	8.77	7.85	Apr. 14, 1931	5	19.00	20.23
Nov. 26, 1930	8	13.66	13.80	May 29, 1931	4	24.21	23.62
Dec. 29, 1930	10	15.72	14.12	Puebla seedling:			
Feb. 10, 1931	10	20.81	20.17	Oct. 10, 1930	10	15.34	16.68
Apr. 13, 1931	10	28.87	28.32	Nov. 21, 1930	4	21.79	29.54
Blake:				Puebla:			
Sept. 15, 1930	6	14.24	11.56	Oct. 23, 1930	10	6.94	5.68
Oct. 10, 1930	10	15.35	15.08	Nov. 21, 1930	10	9.75	8.26
Benik:				Jan. 6, 1931	12	14.24	13.59
Sept. 23, 1930	7	1.73	1.78	Feb. 4, 1931	10	15.20	17.80
Nov. 26, 1930	8	7.47	7.67				
Jan. 6, 1931	9	10.19	9.54				

REDUCING AND TOTAL SUGARS

Church and Chace (*1*) showed that while the total sugar content of the pulp of avocado fruits decreased, the fat content increased. In the present experiments, the fruits were utilized immediately after they were picked in order to avoid changes that are known to affect avocado fruits in storage. Determinations (table 5) were therefore made of the reducing as well as the total (as reducing) sugar content of the stem and tip halves of the pulp (without skin) of several varieties of avocado fruits.

TABLE 5.—*Sugar content of the pulp (without skin) from the stem and tip halves of avocado fruits of several varieties in relation to time of collection*

Variety and date of collection	Fruits	Reducing sugars on basis of—				Total sugar as reducing sugar on basis of—			
		Fresh weight		Dry matter		Fresh weight		Dry matter	
		Stem half	Tip half	Stem half	Tip half	Stem half	Tip half	Stem half	Tip half
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Blake:									
Oct. 10, 1930	10	0.54	0.34	2.09	1.40	0.65	0.52	2.57	2.15
Puebla seedling:									
Oct. 10, 1930	10	.73	.45	2.81	1.52	.90	.58	3.47	1.97
Nov. 21, 1930 [1]	4	.36	.23	1.03	.54	.64	.71	1.85	1.66
Puebla:									
Nov. 21, 1930	10	1.27	.80	6.71	4.16	1.65	1.34	8.71	6.99
Jan. 6, 1931	12	1.12	.77	4.68	3.13	1.46	1.32	6.19	5.39
Feb. 4, 1931	10	1.17	.76	4.33	2.58	2.58	1.03	9.53	3.53
Benik:									
Jan. 6, 1931	9	1.48	.84	7.05	3.62	1.89	1.06	8.98	4.60
Feb. 16, 1931	8	1.09	.80	4.90	3.29	1.27	1.06	5.72	4.52
Apr. 14, 1931	5	.70	.49	2.34	1.56	.87	.74	2.93	2.38
May 29, 1931	4	.25	.19	.80	.60	.49	.47	1.57	1.45
Fuerte:									
Feb. 10, 1931	10	.59	.29	1.98	.98	2.05	1.74	6.84	5.87
Apr. 13, 1931	10	.40	.19	1.11	.51	.47	.55	1.30	1.51
Apr. 30, 1931 [2]	6	.13	.14	.36	.48	.31	.25	.99	.86

[1] Last of crop. [2] Overmature.

The pulp of the stem halves of avocado fruits usually contains more reducing and total (as reducing) sugars than that of the tip halves, and in many cases the nonreducing sugar is higher in the tip than in the stem halves. The differences in sugar content of the halves decreased as the fruits became fully ripe or overmature on the tree. The data confirm the results of Church and Chace (*1*) in indicating a reduction in sugar content with increasing maturity of the fruits. In date fruits of the Deglet Noor variety (*7*), and in citrus fruits (*8*), higher percentages of reducing sugars have been found in the tip than in the stem portion.

INORGANIC CONSTITUENTS OF THE FRUIT

Prior to 1922 when Church and Chace (*1*) incidentally referred to an increase of 0.18 percent in the ash content of the outer, over that of the inner portion of the pulp of an avocado fruit, it was assumed that the skin and pulp were each in themselves uniform in inorganic composition. The results of the present investigation indicate that there is no uniform distribution of the various constituents in avocado fruits.

The first analyses of inorganic constituents of the pulp were made with mature fruits of the Fuerte variety collected at Vista, Calif. The fruits were allowed to soften until edible and were cut into halves along the long axis from stem to tip. There were no consistent differences in the halves, as cut (table 6). The data permit the calculation of the absolute amounts (grams) of the various ash constituents in fruits of various sizes. A single complete calculation for a Fuerte avocado fruit of a given weight is also presented in table 6.

TABLE 6.—*Mineral content, on a dry-matter basis, of pulp (without skin) of Fuerte avocado fruits, halved lengthwise from stem to tip*

Fresh weight			Dry matter	Ash on dry-matter basis	Ca	Mg	K	Na	Inorganic PO_4	Cu	Fe	Mn
Skin (all)	Seed	Pulp halves										
Grams	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Parts per million*	*Parts per million*	*Parts per million*
31	59	168.5	31.47	3.89	0.025	0.095	1.80	0.43	--------	--------	--------	--------
		155.0	31.18	4.22	.023	.097	2.01	.44	--------	--------	--------	--------
26	59	149.0	34.33	4.18	.018	.104	2.01	.47	--------	--------	--------	--------
		135.8	34.43	4.25	.020	.100	2.02	.50	--------	--------	--------	--------
28	34	145.0	29.07	4.75	.023	.116	2.21	.53	--------	--------	--------	--------
		172.0	29.20	4.48	.025	.104	2.11	.47	--------	--------	--------	--------
15	71	146.0	34.82	3.68	--------	--------	--------	--------	--------	17.1	--------	--------
		144.0	35.47	3.40	--------	--------	--------	--------	--------	13.4	--------	--------
14.5	60	143.5	34.98	3.47	--------	--------	--------	--------	--------	14.7	--------	--------
		145.0	34.25	3.74	--------	--------	--------	--------	--------	14.7	--------	--------
14.25	59	141.3	34.10	3.87	.023	.100	1.63	.23	0.34	--------	44	4.9
		154.0	34.11	3.97	.022	.097	1.63	.23	.29	--------	32	5.2
15	74	186.5	31.06	4.52	.025	.110	2.04	.08	.26	--------	28	5.0
		181.5	32.33	3.95	.038	.099	1.83	.16	.54	13.0	46	4.7
13.5	52.5	143.5	31.23	3.91	.064	.218	1.77	.12	.32	--------	29	4.9
		141.0	31.75	3.96	.032	.103	1.81	.15	.33	--------	36	5.4
13.5	81.5	188.0	31.28	3.99	.033	.094	1.83	.16	.54	14.8	46	4.7
		193.5	31.40	3.93	.044	.091	1.77	.13	.52	15.6	42	3.9
			Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Milligrams*	*Milligrams*	*Milligrams*
[1] 13.5	[1] 81.5	188.0	58.8029	2.3446	0.0195	0.0555	1.0748	0.0915	0.3111	0.873	2.68	0.275
		193.5	60.7500	2.3879	.0270	.0555	1.0748	.0785	.3140	.947	2.56	.235

[1] Absolute amounts of ash constituents given for this sample.

Fruits of the Fuerte, Puebla, and Benik varieties collected at various stages of development were cut transversely into stem and tip halves immediately after being picked. The results of analyses of the pulp of these fruits are presented in a series of graphs.

The rate at which the dry matter of the fresh pulp changes with increasing maturity is shown in figure 1, *A*. As the fruits approach maturity (Fuerte and Benik varieties) there is a more or less abrupt change in the slope of the curves. The maximum dry matter in the pulp of Fuerte avocado fruits was approximately 37 percent. In most of the samples the tip halves of the pulp contain a somewhat larger percentage of dry matter than the stem halves. These results not only confirm the data given in table 1 but indicate also that this same condition in the halves exists more or less generally throughout the various stages in the development of the fruit. The percentages of dry matter show large differences in the inner and outer portions of the tip halves of the pulp of Fuerte avocado fruits.

The ash as a percentage of the dry matter of the tip halves of the pulp of Fuerte and Benik avocado fruits is greater than that of the stem halves (fig. 1, *B*). The graphs for the pulp of fruit of these and other varieties not presented confirm and greatly extend the results of Church and Chace (*1*).

Potassium is by far the most abundant constituent of the ash. Potassium occurs in greater concentration in the dry matter of the tip than in that of the stem halves throughout the various stages of development of the fruit (fig. 2, *A*). In figure 2, *A*, some of the curves also show the relative uniformity of the percentages of potassium in the pulp of fruits of different ages; in other curves a decreasing trend is shown.

The percentages of sodium in the dry matter are small. The curves shown in figure 2, *B*, indicate higher percentages of sodium as the fruits develop.

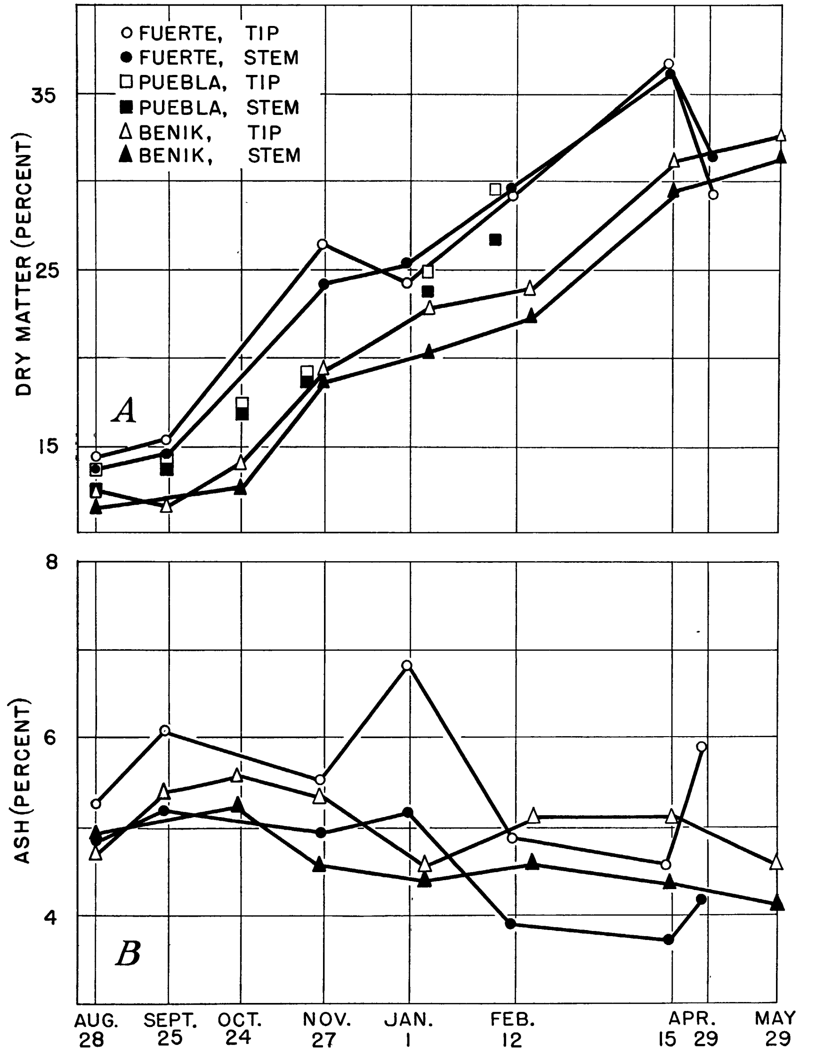

FIGURE 1.—Dry matter (*A*) and ash content (*B*) of the pulp, without skin, from the stem and tip halves of avocados at various stages of development.

The percentage of calcium in the dry matter of the pulp of fruits of the Fuerte, Benik, and Puebla varieties decreases as their season of growth advances (fig. 3, *A*). The stem halves of the pulp contain greater percentages of calcium in the dry matter than the tip halves (fig. 3, *A*), whereas the converse is true in the case of potassium (fig. 2, *A*).

The percentages of magnesium in the stem halves of the pulp are generally greater than those in the tip halves (fig. 3, *B*). The data for magnesium resemble those for calcium, the percentages of magnesium decreasing as the fruits increase in age.

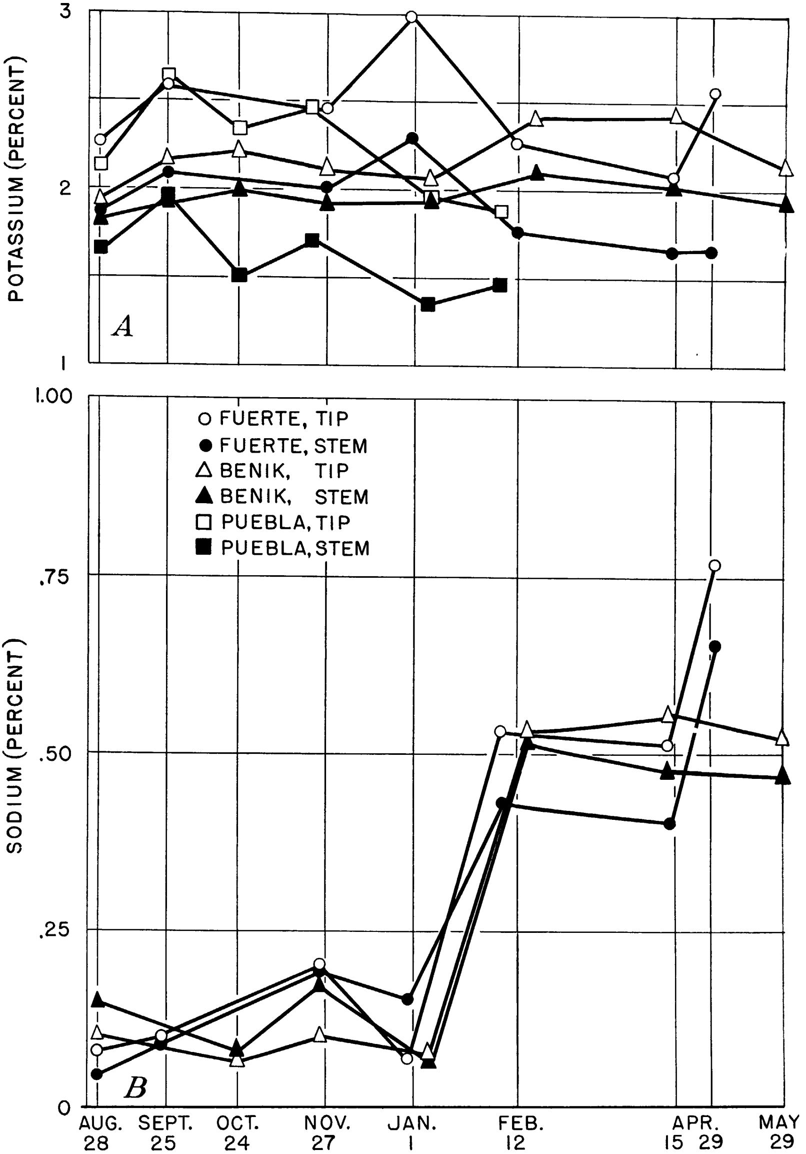

FIGURE 2.—Potassium (*A*) and sodium (*B*) content, on a dry-matter basis, of the pulp, without skin, from the stem and tip halves of avocados, at various stages of development.

The inorganic phosphate as a percentage of the dry matter of the pulp decreases with increasing age of the fruits. The percentages of inorganic phosphate were not uniformly greater in the tip than in the stem halves of pulp (fig. 4). Inorganic phosphate as a percentage of

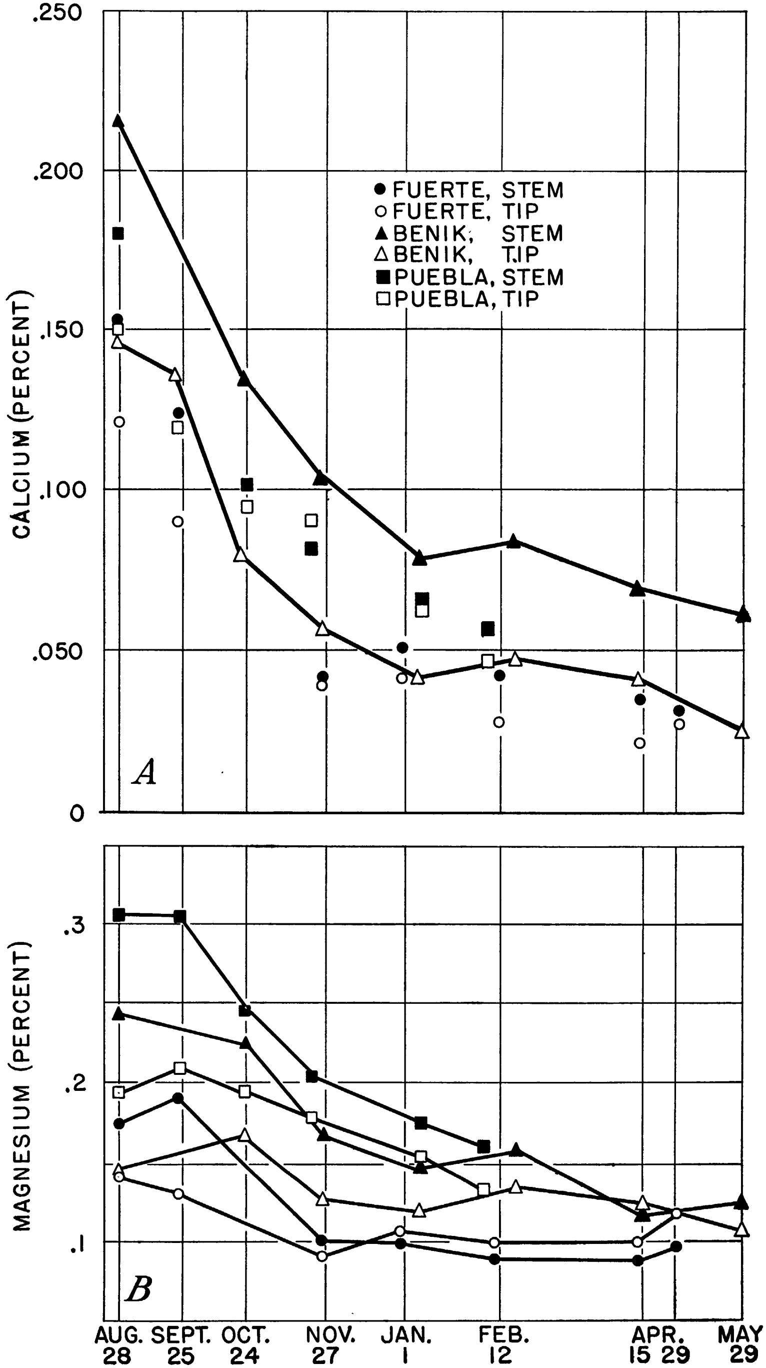

FIGURE 3.—Calcium (*A*) and magnesium (*B*) content, on a dry-matter basis, of the pulp, without skin, from the stem and tip halves of avocados, at various stages of development.

the dry matter of the pulp was somewhat greater in the tip than in the stem halves of Blake avocado fruits. The values for the stem halves were 0.76, 0.82, and 0.66, while those for the tip halves were 0.80, 0.84, and 0.74 for the respective samples (table 7) collected on August 28, September 15, and October 10, 1930. There are no known available data regarding the iron and manganese content of avocado fruits. Data regarding the iron and manganese concentrations in the pulp are presented in table 7. The variations in the values obtained for iron are large and the differences may be merely fortuitous and statistically not significant.

Except in the small fruits, which were of the Blake variety, the manganese content (p. p. m.) in the tip halves of the pulp of the fruits examined exceeds that in the stem halves (table 7). Figure 5 shows that the concentration of manganese decreases as the fruits become older.

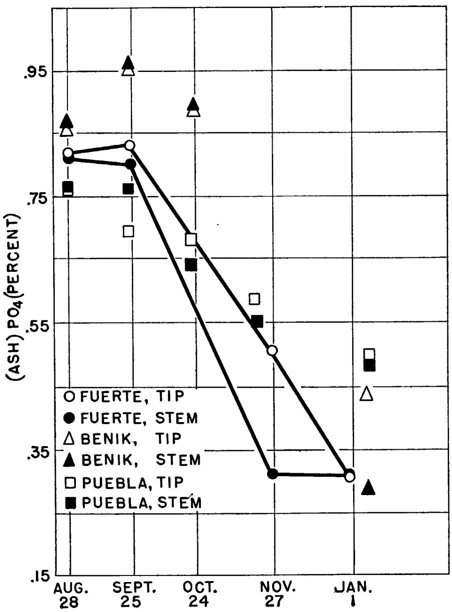

FIGURE 4.—Inorganic phosphate content, on a dry-matter basis, of the pulp, without skin, from the stem and tip halves of avocados, at various stages of development.

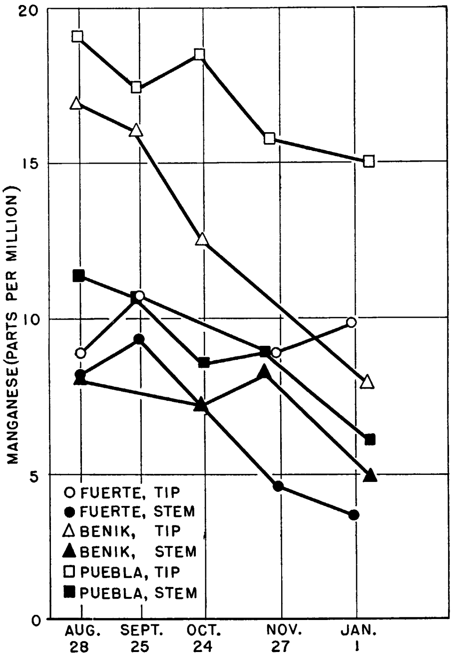

FIGURE 5.—Manganese content, on a dry-matter basis, of the pulp, without skin, from the stem and tip halves of avocados, at various stages of development.

Because of the extremely large number of commercial varieties of avocado fruits, some of the ash constituents of additional varieties were also determined (table 8). Except in the first two samples of Blake avocado fruits, the percentages of calcium are again larger in the stem than in the tip halves. No definite trend was shown by the values for magnesium or sodium, whereas in every case the percentage of potassium in the tip halves exceeds that in the stem halves.

No data are available in the literature in regard to the copper content of avocado fruits. Determinations were made of this constituent in the pulp and skin of mature fruits of the Anaheim variety collected at Fallbrook in June 1933. The limited data (table 9) indicate that the greatest copper content in the pulp was found in the outer portion of the tip half. Large amounts of copper also appear to be present in the skin of the fruit. The variation in the results for the inorganic phosphate content of the two lots of fruit was extremely large.

TABLE 7.—*Iron and manganese content, on a dry-matter basis, of the pulp (without skin) from the stem and tip halves of avocado fruits of several varieties*

Variety and date of collection	Fruits	Iron		Manganese	
		Stem half	Tip half	Stem half	Tip half
	Number	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*
Fuerte:					
Aug. 28, 1930	4	67	26	8.3	8.9
Sept. 23, 1930	7	41	10	9.4	10.7
Nov. 26, 1930	8	41	50	4.6	8.8
Dec. 29, 1930	10	32	28	3.7	9.8
Puebla:					
Aug. 28, 1930	5	23	119	11.4	19.1
Sept. 23, 1930	8	15	28	10.7	17.5
Oct. 23, 1930	10	65	27	8.5	18.5
Nov. 21, 1930	10	19	79	8.8	15.8
Jan. 6, 1931	12	20	51	6.0	15.0
Puebla seedling:					
Sept. 3, 1930	16	32	69	5.8	7.8
Oct. 10, 1930	10	16	18	4.2	6.1
Nov. 21, 1930	4	19	51	4.1	5.5
Benik:					
Aug. 28, 1930	4	30	54	8.0	17.0
Sept. 23, 1930	7	----------	34	----------	16.1
Oct. 24, 1930	8	16	22	7.3	12.5
Nov. 26, 1930	8	55	----------	8.1	----------
Jan. 6, 1931	9	36	48	4.9	7.9
Blake:					
Aug. 28, 1930	5	64	40	10.8	10.2
Sept. 15, 1930	6	73	23	10.0	9.6
Oct. 10, 1930	10	59	54	8.5	8.8

TABLE 8.—*Inorganic base content, on a dry-matter basis, of the pulp (without skin) from the stem and tip halves of avocado fruits of several varieties*

Variety [1]	Fruits	Ash		Calcium		Magnesium		Potassium		Sodium	
		Stem half	Tip half	Stem half	Tip half	Stem half	Tip half	Stem half	Tip half	Stem half	Tip half
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Premier	3	5.93	6.49	0.084	0.059	0.166	0.186	2.60	2.96	0.10	0.13
Lyon seedling	5	5.08	5.55	.064	.044	.148	.131	2.35	2.56	.06	.09
Thompson	3	4.07	5.27	.082	.031	.160	.158	1.84	2.36	.10	.09
Anaheim	4	6.66	7.92	.076	.046	.169	.211	2.92	3.70	.30	.17
Blake	5	4.77	5.83	.045	.050	.154	.132	2.16	2.48	.09	.08
Do	6	5.16	6.18	.047	.073	.129	.159	2.34	2.87	.13	.15
Do	10	3.99	4.90	.040	.027	.115	.119	1.79	2.27	.06	.06

[1] Samples of the fruits of the Blake variety were collected respectively on Aug. 28, Sept. 15, and Oct. 10, 1930; those of the other varieties were collected on Mar. 12, 1930.

The pulp of mature Fuerte, Blake, Puebla, and Benik avocado fruits was next investigated to find any possible differences in the total sulphur, phosphorus, nitrogen, and chlorine content in the stem and tip halves. The data for mature fruits are given in table 10.

TABLE 9.—*Copper and inorganic phosphate content, on a dry-matter basis, of the pulp and skin from the stem and tip halves of Anaheim avocado fruits, 1933*

Part of fruit and date of collection	Fruits	Copper				Inorganic phosphate			
		Inner stem	Outer stem	Inner tip	Outer tip	Inner stem	Outer stem	Inner tip	Outer tip
	Number	*Parts per million*	*Parts per million*	*Parts per million*	*Parts per million*	*Percent*	*Percent*	*Percent*	*Percent*
Pulp:									
June 14	1	30.3	22.0	26.6	34.1	0.894	0.780	0.760	0.885
June 23	2	28.3	23.4	23.6	36.6	.398	.336	.328	.378
Skin: [1]									
June 14	1	32.1	32.1	44.2	44.2	.396	.396	.638	.638
June 23	2	26.7	26.7	19.4	19.4	.659	.659	.556	.556

[1] The skin was separated into stem and tip but not into inner and outer portions, hence the figures are given as the same for both the latter.

TABLE 10.—*Total sulphur, phosphorus, nitrogen, and chlorine content, on a dry-matter basis, of the pulp (without skin) from the stem and tip halves of avocado fruits of several varieties in relation to time of collection*

Variety and date of collection	Fruits	Sulphur		Phosphorus		Nitrogen		Chlorine	
		Stem half	Tip half	Stem half	Tip half	Stem half	Tip half	Stem half	Tip half
Fuerte:	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nov. 26, 1930	8	0.13	0.13	0.13	0.12	1.28	1.43	0.02	-------
Dec. 29, 1930	10	.14	.15	.41	.10	1.30	1.51	.03	0.03
Dec. 30, 1930	10	.16	.21	.11	.14	1.28	1.65	-------	-------
Feb. 10, 1931	10	.10	.11	.11	.34	.77	.97	.03	.03
Apr. 13, 1931	10	.10	.11	.14	.15	.71	.89	.02	.02
Apr. 30, 1931	6	.12	.14	.11	.10	1.03	1.32	.02	.02
Blake:									
Oct. 10, 1930	10	.10	.11	.11	.12	.89	1.03	.05	.09
Puebla:									
Oct. 23, 1930	10	.12	.13	.11	-------	-------	-------	-------	-------
Nov. 21, 1930	10	.12	.12	.11	.12	1.51	1.71	-------	-------
Jan. 6, 1931	12	.08	.10	.11	.10	1.08	1.27	.04	.04
Feb. 4, 1931	10	.08	.08	.11	.11	.91	1.03	.03	.03
Benik:									
Jan. 6, 1931	9	.10	.09	.10	.10	1.21	1.29	.01	.01
Feb. 16, 1931	8	.09	.09	.09	.18	.99	1.16	.02	.02
Apr. 14, 1931	5	.08	.08	.11	.12	.88	.95	.01	.01
May 29, 1931	4	.08	.10	.11	.12	1.01	1.13	.01	.01

The results permit of one definite conclusion, namely, that the percentages of total nitrogen (including nitrates) are greater in the dry matter in the tip than in the stem halves of avocado fruits. This was found to be true in each of the individual sample collections that were made. The dry matter therefore contains higher percentages of both total nitrogen and potassium in the tip than in the stem halves.

The chlorine concentrations in the pulp (table 10) are usually very small. Results on fruits from other locations suggest, however, as will be shown later, that in districts where the irrigation water contains large concentrations of chlorine, higher percentages of total chlorine than those given in table 10 are found. Total sulphur and phosphorus concentrations (table 10) are only about one-tenth that of total nitrogen.

In order to study the effect of high sulphate concentrations in the irrigation water on the total sulphur distribution in avocado fruits, mature fruits [4] of the Challenge, Queen, Spinks, and Taft varieties

[4] These fruits were obtained through the kindness of L. T. Sharp of Santa Paula, Calif.

were obtained at Oxnard, Calif., on September 23, 1933, from trees growing in soil that was irrigated with water containing 350 to 450 parts per million of sulphate. The leaves of the trees from which these fruits were picked were affected with tipburn (*5*).

Although it is highly desirable that the control fruits be of the same variety as, and be collected near, the experimental fruits, it was not feasible in this case to secure such control fruits. Mature fruit samples of the Fuerte and Anaheim varieties (to serve as controls) were obtained on June 15, 1933, at the Citrus Experiment Station, where the sulphate content of the irrigation water is relatively low.

The percentages of total sulphur and phosphorus in the dry matter of the pulp of the control fruits (Fuerte and Anaheim varieties in table 11) are less than those for the fruits obtained from areas high in sulphate. Considerable variation occurred in the percentages of sulphur and phosphorus in the various portions of the pulp and no consistent relation was found for all of the varieties. No consistent relation of total phosphorus to the fruit halves was found in the skin of the fruits of the several avocado varieties used (fig. 6). However, the percentages for total sulphur in the skin (fig. 6) are uniformly greater in the stem than in the tip halves.

TABLE 11.—*Total sulphur and phosphorus content, on a dry-matter basis, of the pulp and skin* [1] *from the stem and tip halves of avocado fruits of several varieties from trees grown in soil containing considerable sulphate, 1933*

[Fuerte and Anaheim grown at Riverside are controls; other varieties grown at Oxnard]

Variety, part of fruit, and date of collection	Sulphur				Phosphorus			
	Inner stem	Outer stem	Inner tip	Outer tip	Inner stem	Outer stem	Inner tip	Outer tip
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fuerte, pulp, June 15	0.080	0.072	0.073	0.096	0.141	0.104	0.111	0.120
Fuerte, skin, June 15	.139	.139	.077	.077	.243	.243	.120	.120
Anaheim, pulp, June 15	.094	.137	.090	.162	.149	.129	.143	.132
Anaheim, skin, June 15	.058	.058	.049	.049	.208	.208	.206	.206
Challenge, pulp, Sept. 23	.188	.199	.175	.197	.280	.203	.230	.263
Challenge, skin, Sept. 23	.078	.078	.052	.052	.204	.204	.157	.157
Queen, pulp, Sept. 23	.196	.186	.219	.218	.302	.209	.246	.266
Queen, skin, Sept. 23	.050	.050	.042	.042	.156	.156	.160	.160
Spinks, pulp, Sept. 23	.190	.200	.230	.216	.189	.266	.193	.310
Spinks, skin, Sept. 23	.054	.054	.048	.048	.165	.165	.191	.191
Taft, pulp, Sept. 23	.147	.150	.144	.139	.220	.192	.180	.191
Taft, skin, Sept. 23	.067	.067	.057	.057	.163	.163	.166	.166

[1] The skin was separated into stem and tip but not into inner and outer portions hence the figures are given as the same for both the latter.

The pulp of mature avocado fruits secured at Riverside, where the irrigation water contained very little chlorine (27 parts per million), showed very small concentrations of this constituent (table 10). In order to compare these data with those of fruits from areas rich in chlorine, mature fruits were secured from groves at Encinitas, Calif., in June 1933, in which the trees showed severe leaf tipburn as a result of excessive concentrations of chlorine (table 12). The chlorine concentration was determined in the inner and outer portions of the stem and tip halves of the pulp and skin. The fruits were mature, except those of the Itzamna variety, and were allowed to soften before being analyzed.

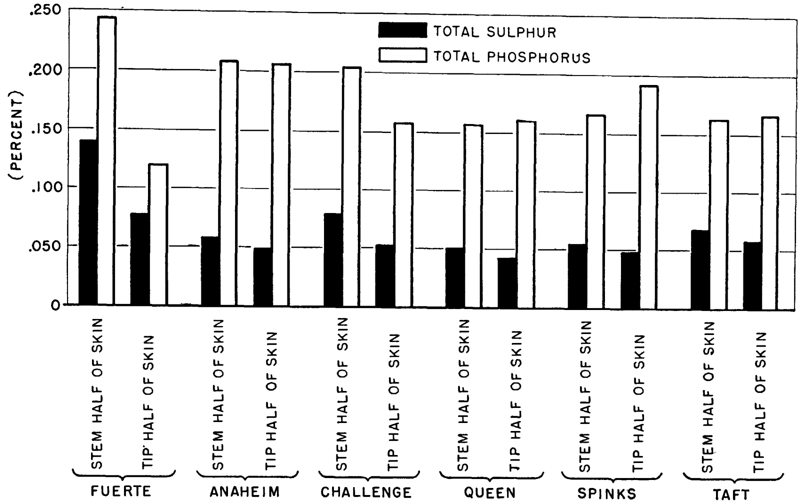

FIGURE 6.—Total sulphur and phosphorus content, on a dry-matter basis, of the skin from the stem and tip halves of six varities of avocado; Fuerte and Anaheim came from trees in control areas and Challenge, Queen, Spinks, and Taft from trees in high-sulphate areas.

The greater amount of chlorine is found in the pulp of fruits from trees bearing leaves which have been injured by chlorides (tables 10 and 12). The pulp and the skin of the tip halves contain smaller percentages of chlorine than the pulp and skin of the stem halves and in each of the varieties studied, the outer portion contains smaller percentages of chlorine than the inner portion of the same halves of pulp (table 12). These results show an inverse relation to potassium.

TABLE 12.—*Total chlorine content, on dry-matter basis, of mature avocado fruits of several varieties obtained from areas containing high chlorine*

Variety	Fruits	Pulp				Skin	
		Stem half		Tip half		Stem half	Tip half
		Inner portion	Outer portion	Inner portion	Outer portion	Entire	Entire
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Anaheim, lot 1	1	0.260	0.200	0.180	0.170	0.380	0.240
Anaheim, lot 2	1	.220	.170	.160	.150	.360	.270
Dickinson	2	.140	.100	.100	.080	.330	.270
Fuerte	3	.084	.060	.049	.037	.780	.770
Itzamna [1]	2	0.073		0.064		.400	.350

[1] Immature fruits.

The results on the chlorine content of the pulp and the skin of mature avocado fruits have been extended to include many varieties growing in soils the solutions of which contain various concentrations of chlorine. The data in table 13 give added support to the view that the skin and the pulp of avocado fruits may accumulate chlorine to a considerable degree when this constituent is present in large concentrations in the soil solution. In general, both the skin and the pulp of the stem halves contain higher percentages of chlorine than the corresponding parts of the tip halves.

TABLE 13.—*Total chlorine content, on a dry-matter basis, of avocado fruits of several varieties from trees grown in soil irrigated with water containing various concentrations of chlorine*

Place and date of collection	Part of fruit and variety	Fruits	Amount of chlorine in irrigation water and extent of tipburn	Cl in— Stem half	Cl in— Tip half
		Number		*Percent*	*Percent*
Riverside:	Pulp:				
Oct. 23, 1930	Puebla	10	27 parts per million	0.046	0.043
		10		.042	.038
Oct. 24, 1930	Benik	8		.015	.014
Oct. 27, 1930		6		.0122	.0117
Oct. 23, 1930	Fuerte	2		.033	.028
Carlsbad: Dec. 30, 1930		1	Moderate; more than 27 parts per million; no leaf tipburn.	.090	.060
		1	Extreme; bad leaf tipburn; defoliation.	.063	.045
Encinitas: Mar. 26, 1930	do	1		.102	.097
		1		.301	.267
Fallbrook: Mar. 12, 1930	do	5		.148	.127
Riverside:	Skin:				
Mar. 19, 1930	Guatemalan seedling.	2	27 parts per million	.031	.024
Feb. 1, 1930	Mayapan	1		.022	.029
Fallbrook: Mar. 27, 1930	Anaheim	6	Moderate: more than 27 parts per million; no leaf tipburn.	.150	.060
	Lyon seedling	7		.130	.090
	Premier	5		.190	.110
	Thompson	6		.135	.096
Near Tustin: Mar. 28, 1930.	Challenge	1	High; leaf tipburn	.052	.039
		1		.127	.096
Santa Ana: Feb. 7, 1930	do	1		.178	.144
Near Tustin: Mar. 28, 1930.	do	1		.160	.120
Encinitas: June 23, 1933	Fuerte	3		.780	.770
Fallbrook: Mar. 12, 1930		12	Extreme; bad leaf tipburn; defoliation.	.020	.940
Encinitas: Mar. 26, 1930	do	3		1.170	.970
		1		1.280	1.000

When avocado trees are grown under conditions of extremely high chlorine in the soil solution, the percentage of chlorine in the pulp may be increased to about two to seven times that found in fruits grown in districts where the soil solution contains very little chlorine (table 13). The data in table 13 also show the large concentrations of chlorine in the skins of Fuerte fruits from trees grown in soils containing high chlorine. Fuerte skins of this group contained over 1 percent of chlorine in the dry matter, whereas the pulp contained only about 0.1 to 0.3 percent. In the case of Fuerte avocado fruit skins, special care was exercised to remove all traces of pulp from the inside of the thin skin. The results leave no doubt that the high chlorine in the Fuerte skins was actually due to the chlorine in the skins and not to that of adhering pulp, for the pulp alone contained much lower percentages.

These results have not been affected by the adherence of soil, for many of the fruits were high up in the trees and none were allowed to touch the ground. The further precautions of washing the fruits in running, distilled water and drying them with filter paper were used to exclude chlorine contaminations. The high percentages of chlorine in the skins are of interest because as Fuerte fruits become overmature, certain areas of the skin may darken very readily and the tissues die, permitting easy entrance to decay organisms. The writer (*6*) has already described the death of cells surrounding the stomata of mature Fuerte fruits. An excessive accumulation of ions, such as chlorine and potassium, may be responsible in part for skin-tissue break-down, and hence be related to the problems of storage. The relation of chlorine to break-down of skin tissue in avocado fruits deserves further study.

No analyses of the skin of avocado fruits are at present available other than those just reported. Therefore a study of the concentration of bases in the skin is included in the present investigation.

The percentages of the various bases in the skin of mature avocado fruits of a large number of varieties collected at various locations during 1930–31 are given in table 14. The most striking results are those for calcium, the percentages of which are consistently greater in the dry matter of the skin of the stem half. A second point of interest is that the percentages of ash, calcium, magnesium, sodium, and potassium are greatest in the skin of the fruits of the Fuerte and Benik varieties. The iron content of the dry matter of the tip half of the skin of a fruit (table 9) of the Anaheim variety collected at Fallbrook, on June 23, 1933, was 28 parts per million, and that of whole skins of Fuerte avocado fruits collected at Carlsbad and at Leucadia (table 14) was 248 and 129 parts per million, respectively. The manganese content of the whole skins of Fuerte avocado fruits (table 14) from Carlsbad, Leucadia, and Vista, was 26, 22, and 31 parts per million respectively. The iron content of the skins far exceeds that of manganese. Analyses of the ash of the whole skins of Fuerte avocado fruits from Carlsbad revealed 0.68 percent of inorganic phosphate in the dry matter, while the samples from Leucadia and Vista showed 0.40 and 0.54 per cent, respectively.

TABLE 14.—*Inorganic base content, on a dry-matter basis, of the ash of the skin from the stem and tip halves of avocado fruits of several varieties*

Variety and date of collection	Place of collection	Fruits	Ash		Calcium		Magnesium		Potassium		Sodium	
			Stem half	Tip half	Stem helf	Tip half	Stem half	Tip half	Stem half	Tip half	Stem half	Tip half
		No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Fuerte,[1] Dec. 30, 1930	Carlsbad	2	10.87	10.87	0.200	0.200	0.240	0.240	4.70	4.70	0.52	0.52
Fuerte,[1] Dec. 29, 1930	Leucadia	2	9.36	9.36	.142	.142	.220	.220	4.46	4.46	.45	.45
Fuerte,[1] Jan. 20, 1931	Vista	6	7.67	7.67	.150	.150	.330	.330	3.43	3.43	.34	.34
Do	Puente	6	9.35	9.21	.388	.244	.317	.266	4.26	4.43	2.54	1.09
Fuerte, Mar. 26, 1930	Leucadia	6	8.92	10.03	.238	.117	.291	.293	4.22	4.77	.90	1.27
Benik, May 7, 1930	Riverside	5	9.62	7.52	.704	.196	.239	.248	3.96	3.33	.94	.83
Mayapan, Feb. 1930	do	3	4.30	4.12	.118	.065	.192	.209	1.95	1.88	.48	.45
Mayapan, Mar. 22, 1930	do	5	3.97	3.74	.104	.064	.127	.126	1.85	1.83	.45	.44
Challenge, Mar. 28, 1930	Tustin	6	3.75	3.72	.233	.115	.223	.204	1.07	1.18	.63	.55
Anaheim, Mar. 12, 1930	Fallbrook	6	3.34	2.97	.098	.051	.150	.148	1.40	1.34	.46	.35
Thompson, Mar. 12, 1930	do	6	3.05	3.24	.114	.039	.132	.111	1.38	1.59	.34	.38
Premier, Mar. 27, 1930	do	5	2.82	2.33	.106	.044	.101	.084	1.26	1.10	.29	.25
Premier, Mar. 12, 1930	do	5	2.55	2.19	.220	.062	.142	.085	1.04	.97	.20	.23
Lyon seedling, Mar. 27, 1930	do	7	3.01	2.66	.122	.053	.146	.125	1.29	1.18	.32	.29
Guatemalan seedling R1, T5, Mar. 30, 1930	Riverside	2	3.49	3.06	.118	.063	.114	.114	1.57	1.41	.36	.34
Guatemalan seedling R1, T9, Mar 21, 1930	do	3	2.96	3.43	.127	.056	.121	.151	1.23	1.51	.30	.35
Guatemalan seedling R1, T9, Mar. 18, 1930	do	3	3.09	3.25	.140	.061	.120	.131	1.36	1.52	.33	.37

[1] Whole fruits, unseparated into stem and tip halves, used.

The striking differences in the chemical composition of the skins of avocado fruits are shown in table 14. Certain of the varieties, for example, the Guatemalan seedling, have thick, leathery skins, and a relatively low ash. The Fuerte fruit skin is unique in its high percentage of potassium, which frequently is more than twice that found in the pulp. The high percentages of potassium, together with the high chlorine in the skins of fruits from districts that have high chlorine in the soil, suggest possible reasons for the difficulties in handling mature Fuerte fruits.

SUMMARY

The actual acidity in the pulp (without skin) in avocado fruits increases outwardly toward the skin and also increases from the stem toward the tip end, in the inner as well as in the outer portions. This indicates that the outer better aerated tissues are more acid because carbon dioxide, which tends to make the tissues more alkaline, is more quickly removed. The gradients in the acidity may be related to the distribution of stomata in the skin and their distance from the portion of pulp tested.

No consistent differences were found between the fat content of the stem and tip halves of the pulp of avocado fruits.

The pulp (without skin) of the stem halves of avocado fruits contains slightly more reducing and total (as reducing) sugars than that of the tip halves, and in many cases the nonreducing sugar is higher in the tip than in the stem halves. The data indicate a reduction in sugar content with increasing maturity of the fruits. Differences in the content of sugars in the two halves of pulp nearly disappear as maturity is approached.

The halves of pulp of Fuerte avocado fruits cut lengthwise from the stem to the tip end contain approximately equivalent amounts of chemical constituents. Data are given regarding the grams of the various inorganic constituents in a fruit of a given weight.

The tip halves of the pulp (without skin) usually contain in the fresh weight slightly higher percentages of dry matter than the stem halves. As the Fuerte and Benik avocado fruit samples approach maturity, a somewhat marked change occurs in the slope of the curves for the dry-matter percentages.

The ash as a percentage of the dry matter of the tip halves of the pulp of Fuerte avocado fruits is greater than that of the stem halves.

Potassium is the most abundant constituent of the ash and occurs in greater concentration in the tip halves of the pulp of Fuerte avocado fruits than in the stem halves.

The sodium content of the pulp is small but the percentages in the dry matter increase as the fruits develop.

The percentages of calcium in the pulp of Fuerte avocado fruits are small. The stem halves of the pulp contain greater percentages of calcium in the dry matter than the tip halves. The direction of the calcium gradient in the pulp halves is opposite to that of potassium.

The inorganic phosphate, as a percentage of the dry matter, decreases with increasing age of the fruits.

Data are given regarding the iron and manganese content of the various portions of the pulp. The differences in the iron content of fruit halves do not appear to be statistically significant. The concentrations of manganese in the tip halves of the pulp of fruits of the Fuerte, Puebla, and Benik varieties exceed those in the stem halves. The manganese content in the fruit halves decreases as the fruits become older.

Both the skin and pulp of Anaheim avocado fruits contain relatively large concentrations of copper in the pulp and skin. The largest copper content in the pulp occurs in the outer portion of the tip half.

The percentages of total nitrogen (including nitrates) are greater in the dry matter in the tip than in the stem halves of avocado fruits.

The percentages of total sulphur and total chlorine are greater in the stem than in the tip halves of the dry matter of the skin of avocado fruits.

The pulp and the skin of the tip halves of avocado fruits, grown under conditions of high chlorine, contain smaller percentages of chlorine than the pulp and the skin of the stem halves. In each of the varieties studied, the outer portion contains smaller percentages of chlorine than the inner portion of the same halves of pulp. The skin and pulp of avocado fruits may accumulate chlorine to a considerable degree when chlorine is present in large concentrations in the soil solution. It is possible that chlorine may be involved in the break-down of tissue in the skin of overmature avocado fruits.

The percentages of calcium in the dry matter of the skin of avocado fruits are greater in the stem than in the tip halves. Higher percentages of ash, calcium, magnesium, sodium, and potassium are found in the skin of fruits of the Fuerte and Benik varieties than in that of fruits of several other varieties studied.

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